Measuring the astrophysical S-factor in plasmas: A preliminary test

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Electron Bulk Perturbation Induced by Radioactive Nuclei

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A strong perturbation of the conduction electrons accompanying the radioactive decay of nuclei is discussed. It is demonstrated that this effect depends strongly on recombination phenomena. A resonant behavior of the excitation process as a function of temperature is predicted.

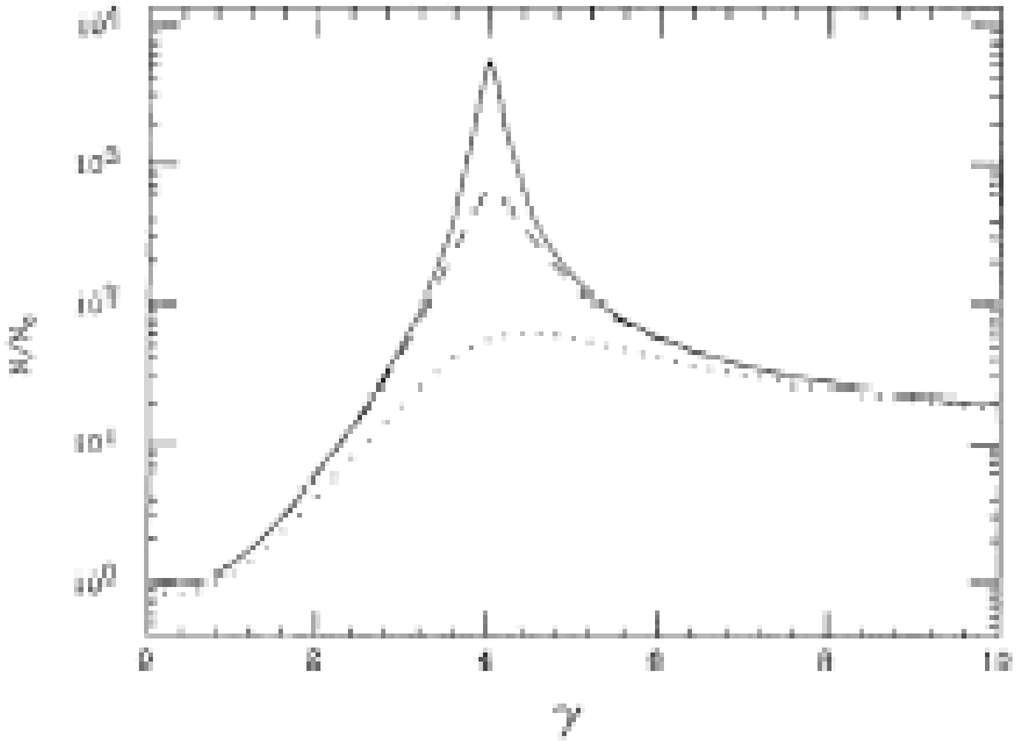


FIG. 4. Temperature ($\gamma = D_e/v_F r_D$) dependence of the total number of excited electrons for $\epsilon_0 \tau_{rec} = 30$ (full line), 10 (dashed), and 3 (dotted).

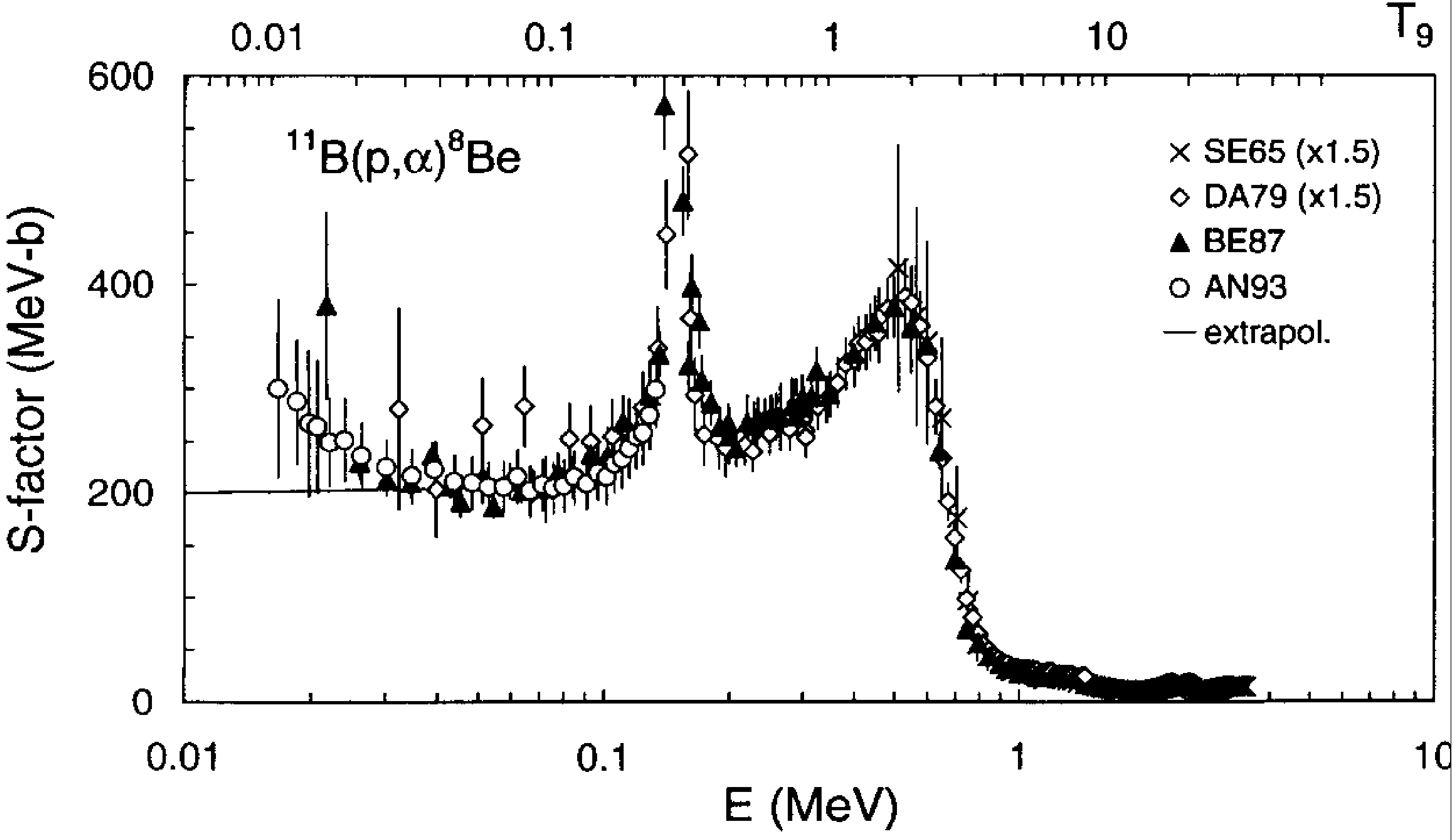
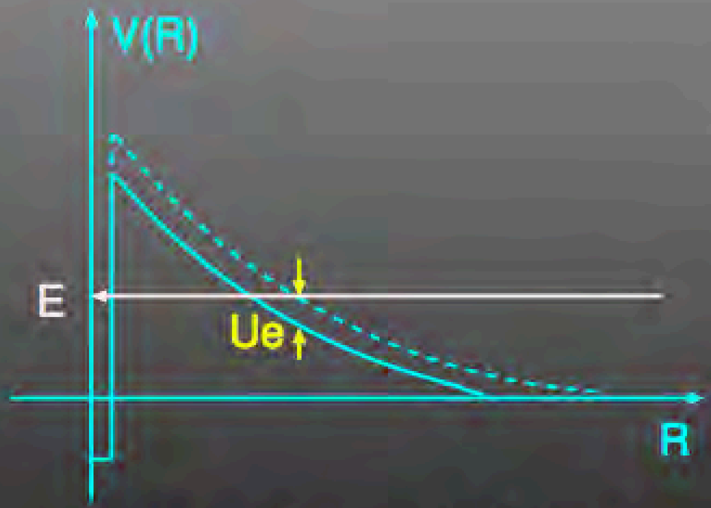


fig.1: S-factor Nacre-compilation

S_0=187 MeV; potenziale screening U_e=430 eV

Screening Energy



U_e : Screening Energy

$$f_e = \frac{\sigma(E)}{\sigma_0(E)} = \frac{\sigma_0(E+U_e)}{\sigma_0(E)}$$

$$\sim \exp\{\pi\eta(E)\frac{U_e}{E}\}$$

$$U_e \sim \frac{E}{\pi\eta(E)}\log f$$

Test for atomic ground states where masses and forces (Coulomb) are exactly known

Constrained Molecular Dynamics (CoMD)

S.Kimura and A.Bonasera, Phys. Rev. A **72**, 014703 (2005)

Lagrange multiplier method for constraints

$$\mathcal{L} = \sum_i \frac{p_i^2}{2m_i} - \sum_{i,j(\neq i)} U(\mathbf{r}_{ij}) + \sum_{i,j(\neq i)} \lambda_i \left(\frac{\mathbf{r}_{ij}\mathbf{p}_{ij}}{\xi\hbar} - 1 \right)$$

$$\mathbf{r}_{ij} = |\mathbf{r}_i - \mathbf{r}_j|; \ \mathbf{p}_{ij} = |\mathbf{p}_i - \mathbf{p}_j|$$

$$\xi = 1(\text{forHeisenbergprinciple})$$

Variational calculus leads Hamilton Equation with Constraint:

$$\frac{d\mathbf{r}_i}{dt} = \frac{\mathbf{p}_i}{m_i} + \frac{\lambda_i \mathbf{r}_{ij}}{\xi\hbar}\frac{\partial \mathbf{p}_{ij}}{\partial \mathbf{p}_i}$$

$$\frac{d\mathbf{p}_i}{dt} = -\nabla_{\mathbf{r}} U(\mathbf{r}_i) - \frac{\lambda_i \mathbf{p}_{ij}}{\xi\hbar}\frac{\partial \mathbf{r}_{ij}}{\partial \mathbf{r}_i}$$

•

Convergence of Atomic G.S.

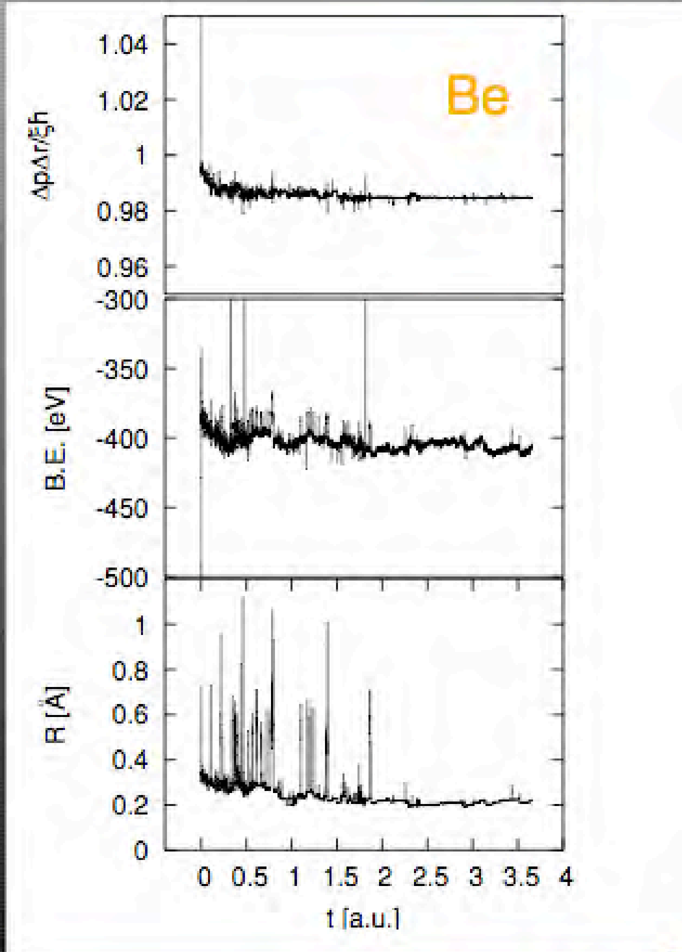
Constraint changes

Phase Space Occupation

$f(r,p,t) \leq 1$

Binding energies of Atoms(in eV)

	CoMD	exper.
H	-13.56	-13.61
He	-77.70	-78.88
Li	-203.78	-203.43
Be	-404.91	-399.03
F	-2644.4	-2713.45



Tunneling process

$$\frac{d\mathbf{r}_i}{dt} = \frac{\mathbf{p}_i}{m_i}; \qquad \frac{d\mathbf{p}_i}{dt} = -\nabla_{\mathbf{r}} U(\mathbf{r}_i)$$

Collective coordinates and momenta

$$\mathbf{R}^{\mathrm{coll}} \equiv \mathbf{r}_P - \mathbf{r}_T; \quad \mathbf{P}^{\mathrm{coll}} \equiv \mathbf{p}_P - \mathbf{p}_T; \quad \mathbf{F}_P^{\mathrm{coll}} \equiv \dot{\mathbf{P}}^{\mathrm{coll}}$$

$$\frac{d\mathbf{r}^{\Im}_{T(P)}}{d\tau} = \frac{\mathbf{p}^{\Im}_{T(P)}}{m_{T(P)}}; \qquad \frac{d\mathbf{p}^{\Im}_{T(P)}}{d\tau} = -\nabla_{\mathbf{r}} U(\mathbf{r}^{\Im}_{T(P)}) - 2\mathbf{F}^{\mathrm{coll}}_{T(P)}$$

Tunneling penetrability: $\Pi(E) = \left(1 + \exp\left(2\mathcal{A}(E)/\hbar\right)\right)^{-1}$

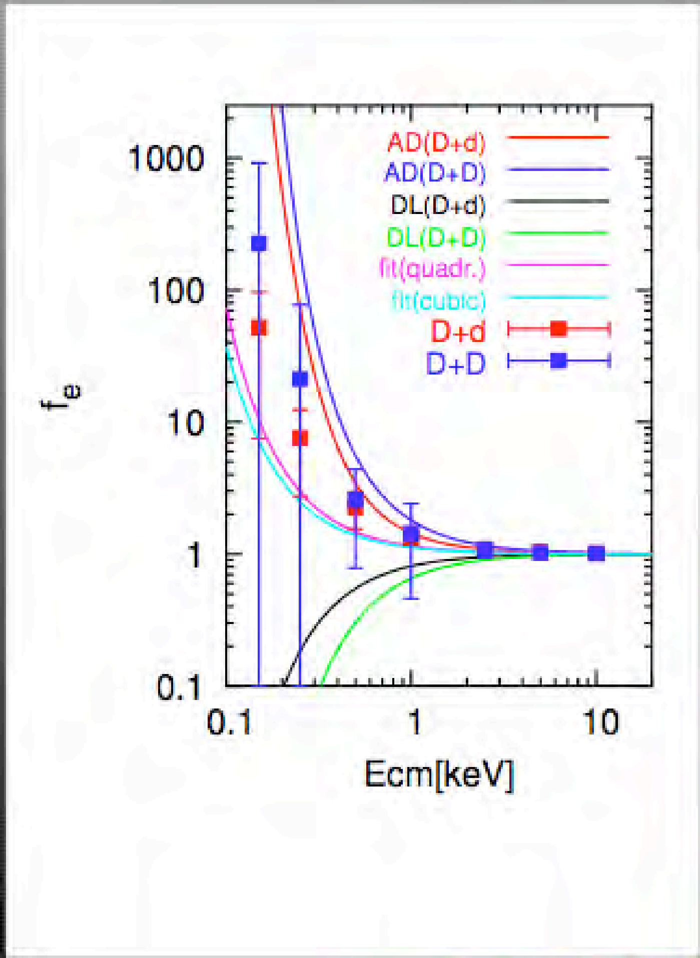
$$\mathcal{A}(E) = \int_{r_b}^{r_a} \mathbf{P}^{\mathrm{coll}}\, d\mathbf{R}^{\mathrm{coll}}$$

without electron $\Rightarrow \Pi_0(E)$

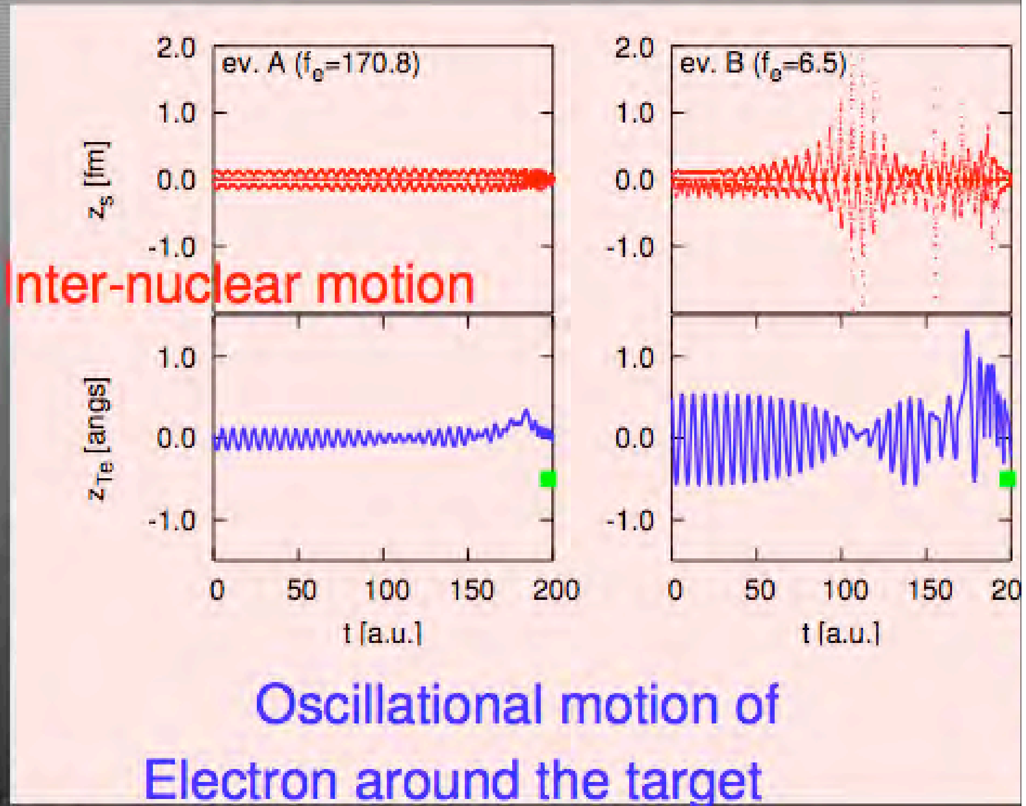
Enhancement factor: $f_e = \Pi(E)/\Pi_0(E)$

Dissipative Limit

Bound electron emission



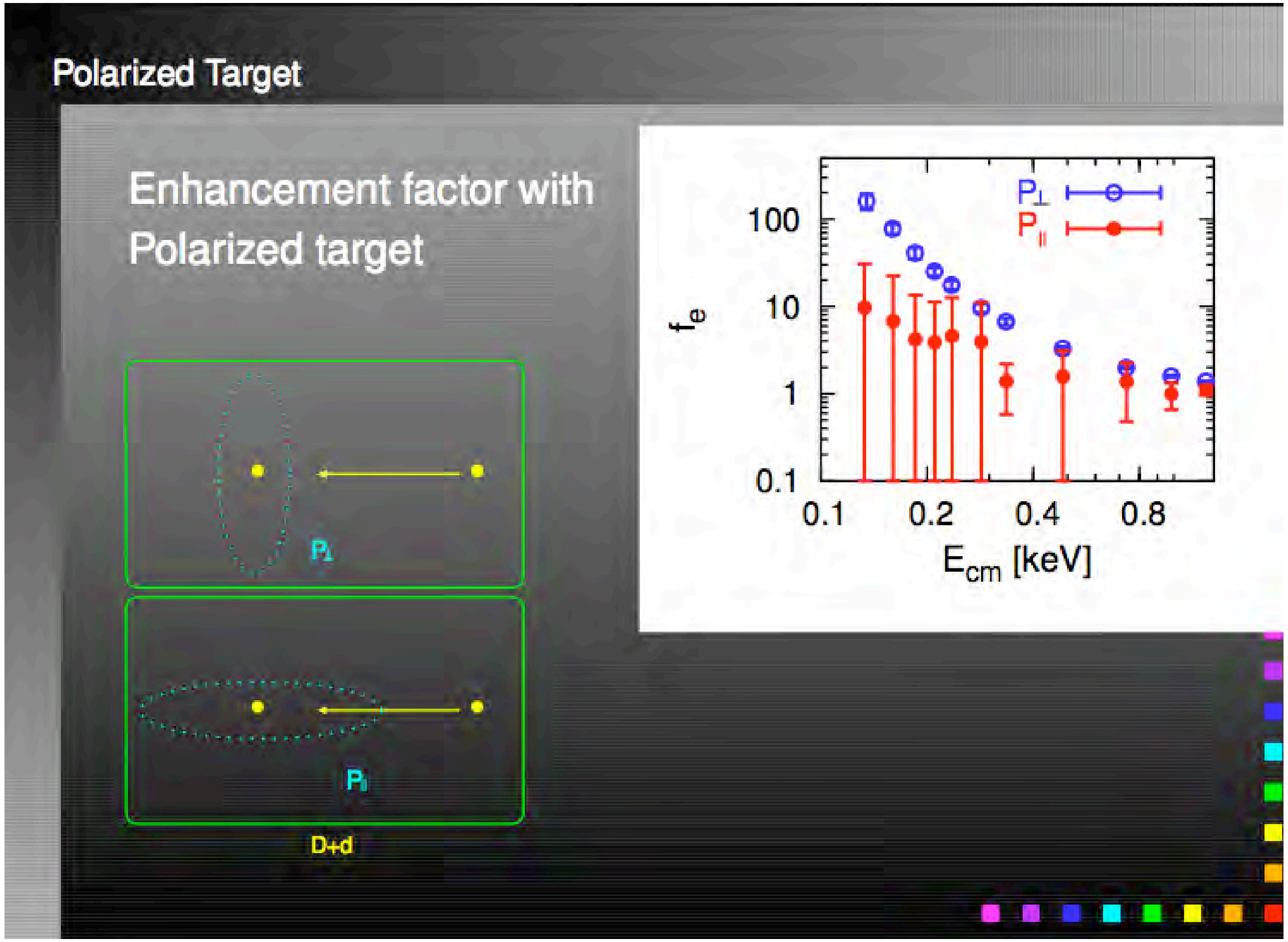
Electronic Motion



S.Kimura, and A.Bonasera
Phys.Rev.Lett.93, 262502(2004)

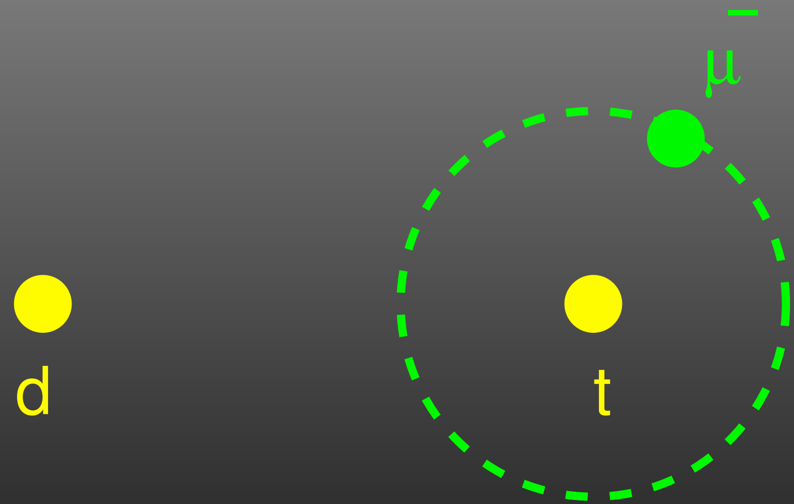
Sensitive Initial Phase

Space Configuration Dependence ⇒ Chaos



Polarized Target
Enhancement factor with
Polarized target
P⊥
P∥
D+d
100
10
1
0.1
0.1
0.2
0.4
0.8
f_e
E_{cm} [keV]

Muon Catalyzed Fusion



μ^- : 200 x heavier than e^-

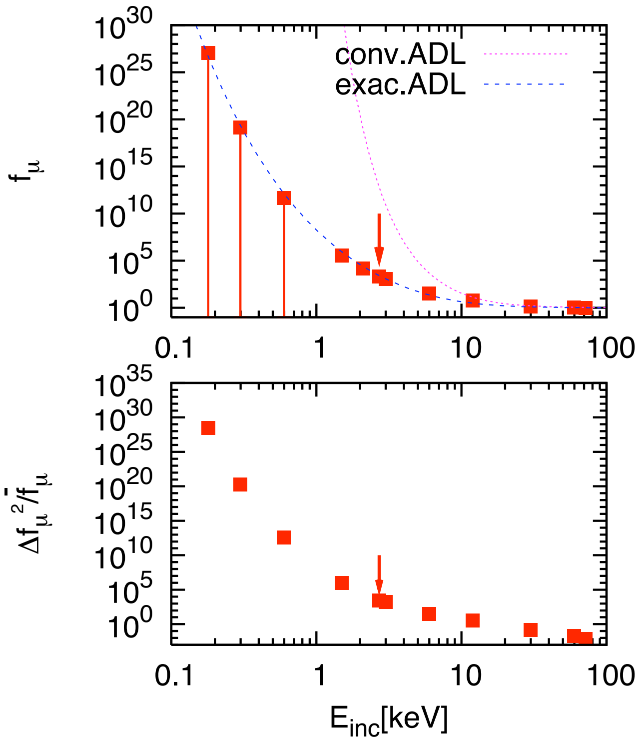


FIG. 1: Enhancement factor by the bound muon (top panel) and $\Delta f_\mu^2/\bar{f}_\mu$ (bottom panel) as functions of the incident center-of-mass energy. The arrows in the figure indicate the point where total energy is zero.

S.Kimura and A.B.

Simulate fusion in plasmas: Mean free path approach.

At each time step we search the closest particle l to each ion k and calculate the local density ρ and the relative velocity v_{kl} , from this we obtain the fusion cross section (parametrized from data) σ.

Define the local mean free path for particles k and l at time t:

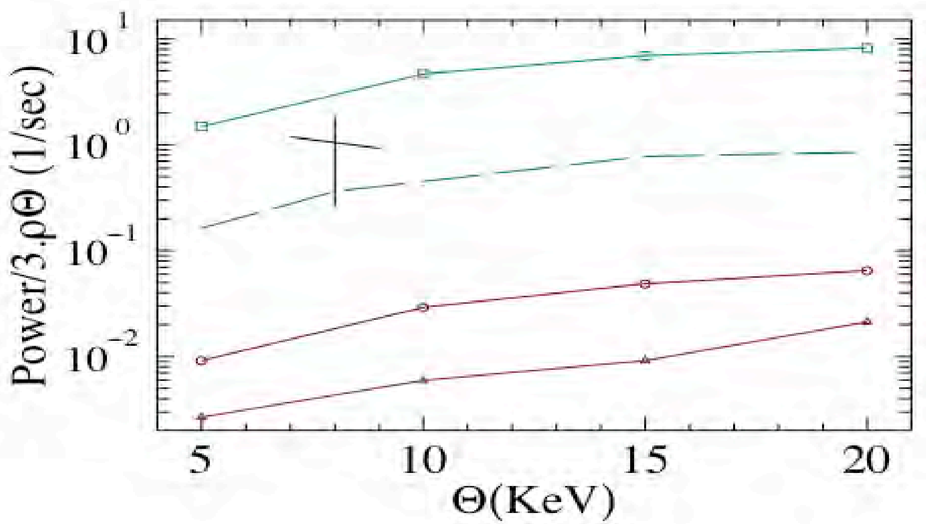
$$\Pi = \frac{v_{kl} dt}{\lambda} = \rho\sigma(r_k) v_{kl} dt$$

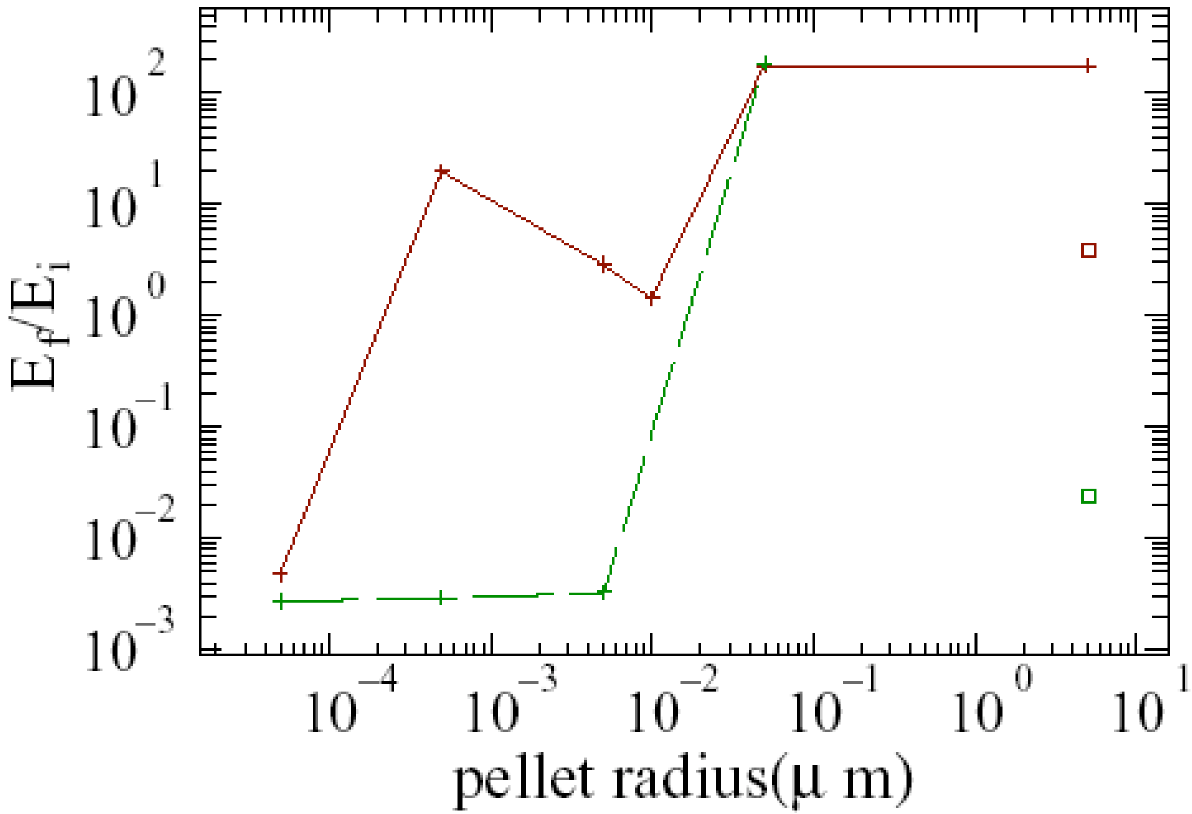
In a Montecarlo way it is decided if the two ions fuse and the reaction is performed according to the Q-value.

A.Bonasera, fusion03, Progr.Theo.Phys.Suppl.**154**,261(2004)

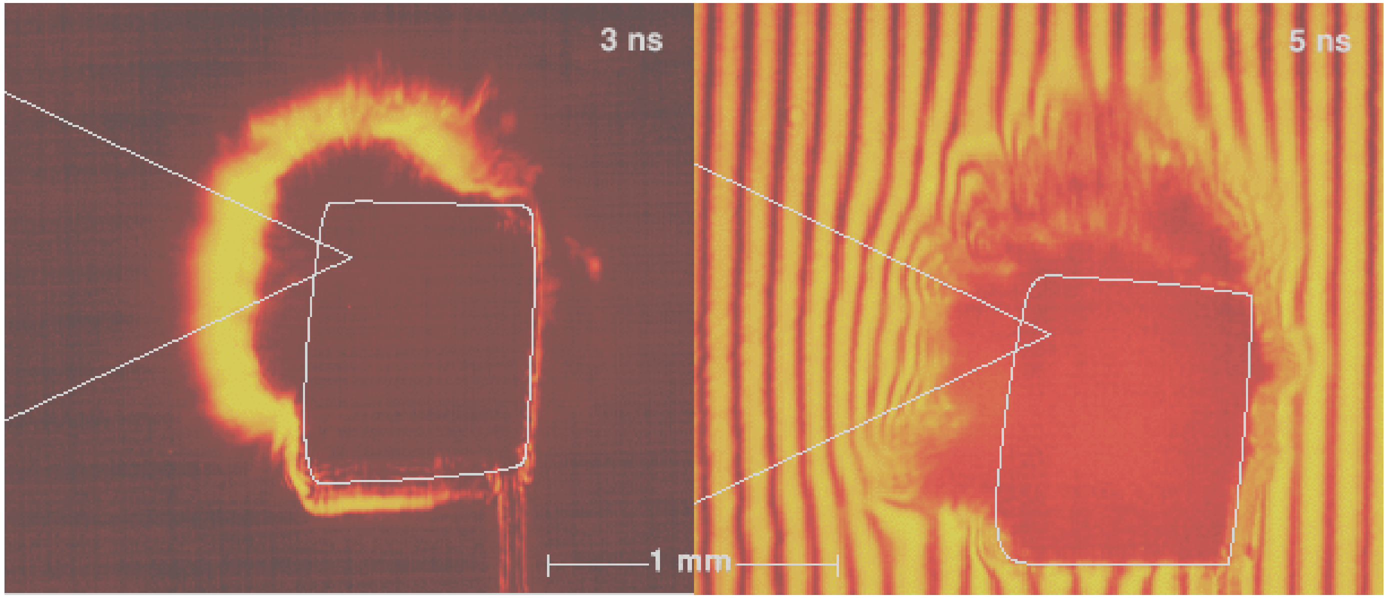
Tokamak case: JET & ITER

D+T (squares), D(circles) and D+Li (triangles) at 9.8 $10^{19}m^{-3}$ density. D+T (dashed line) and JET result (cross) at $10^{19}m^{-3}$ density.





- D+T E_i=50, 5 KeV
- D E_i=50, 5 KeV



Experiments on low density foams. The dashed lines represent the irradiation cone and the initial target position.

ABC LASER facility, Frascati Rome

100 J 3 ns

(A.Caruso and C.Strangio)

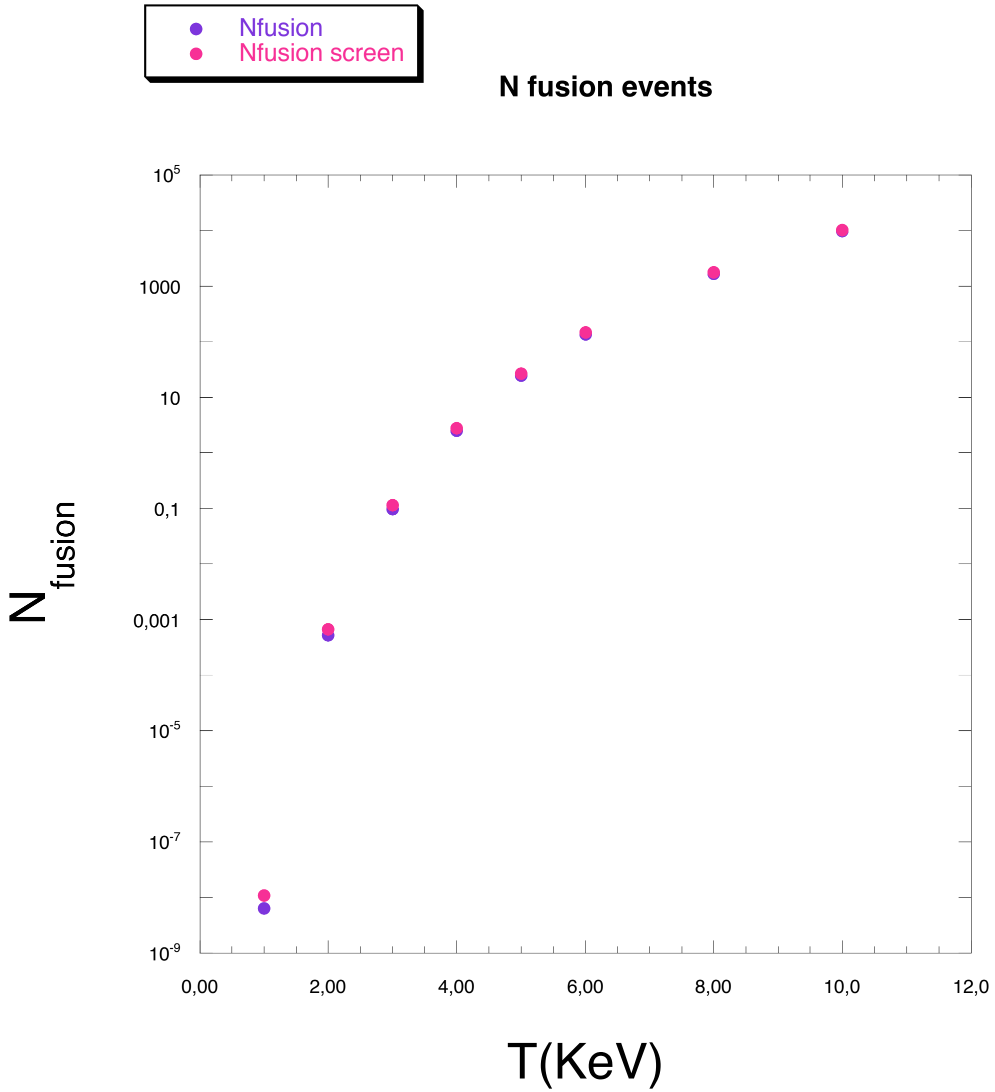
$$N = \iint dV\, dt\, n_1 n_2 \langle \sigma_{12} v \rangle, \quad (6)$$

$n = 10^{20}\,cm^{-3}$

$t = 3ns$

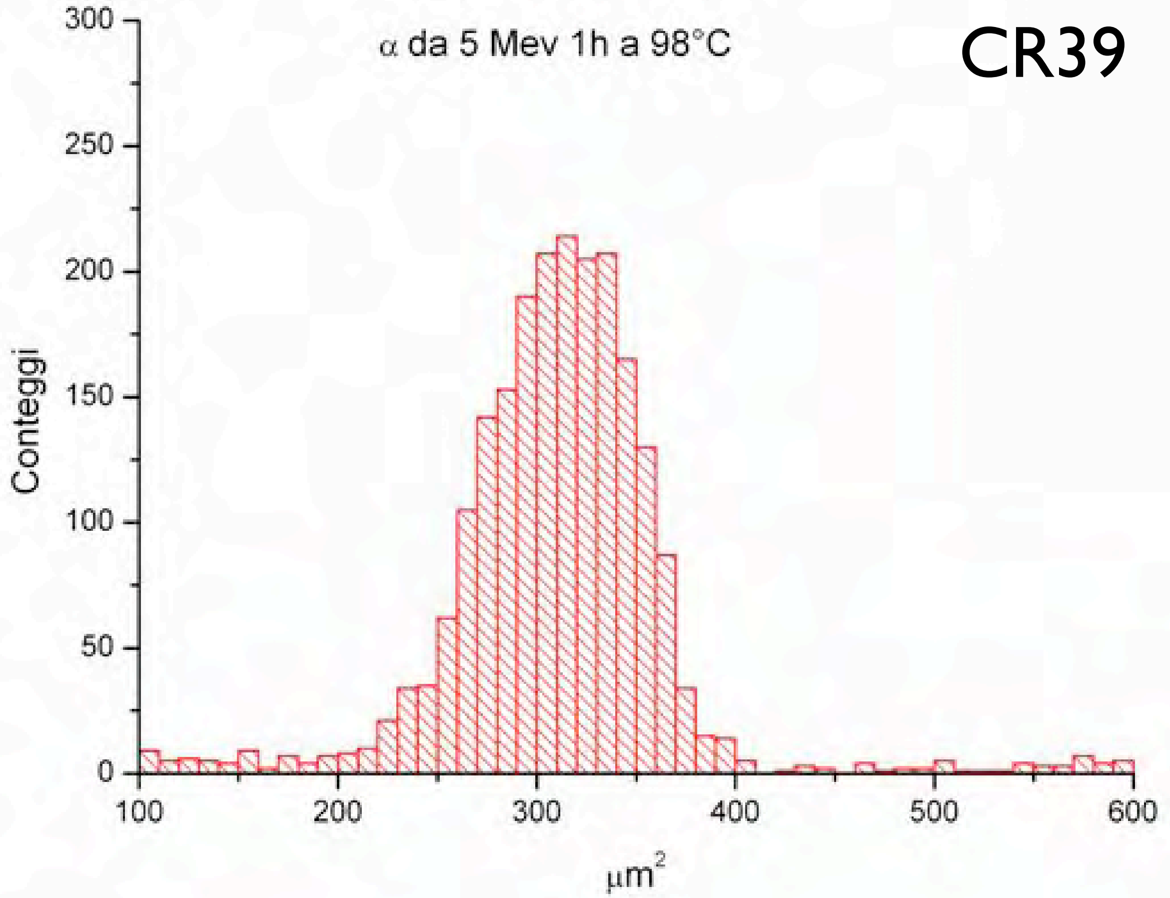
$V = 10^{-6}\,cm^{3}$

Fig.3 Numero di fusioni aspettato utilizzando la compilazione Nacre + potenziale di schermatura U_e=430eV. Il plasma è descritto come una Maxwelliana a temperatura T.



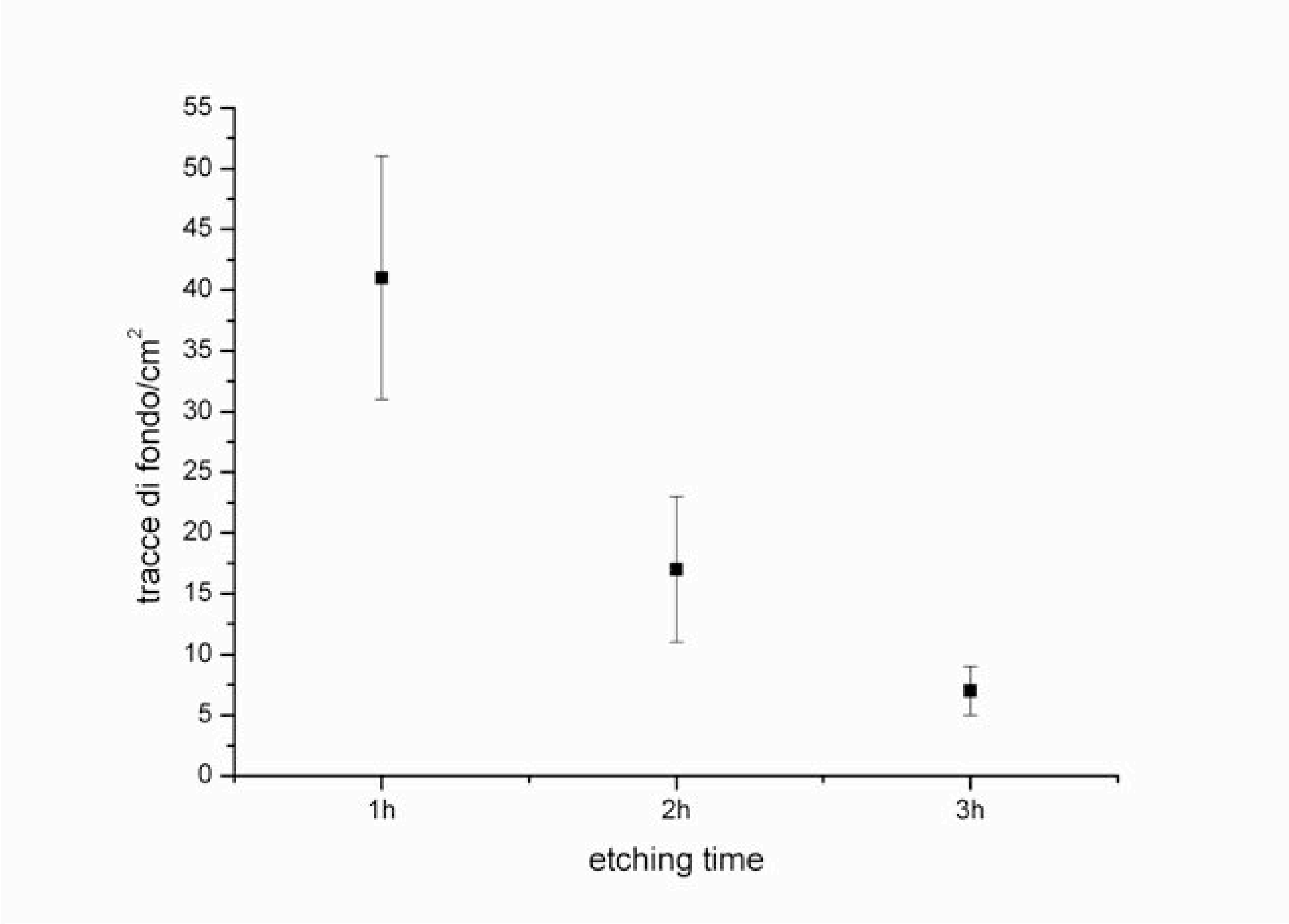
In particolare a 5KeV abbiamo 24 (26 con lo screening) eventi di fusione per sparo e 0.097 (0.1134) a 3KeV.
Queste sono temperature accessibili utilizzando il laser ABC.

Caratterizzazione degli eventi nucleari

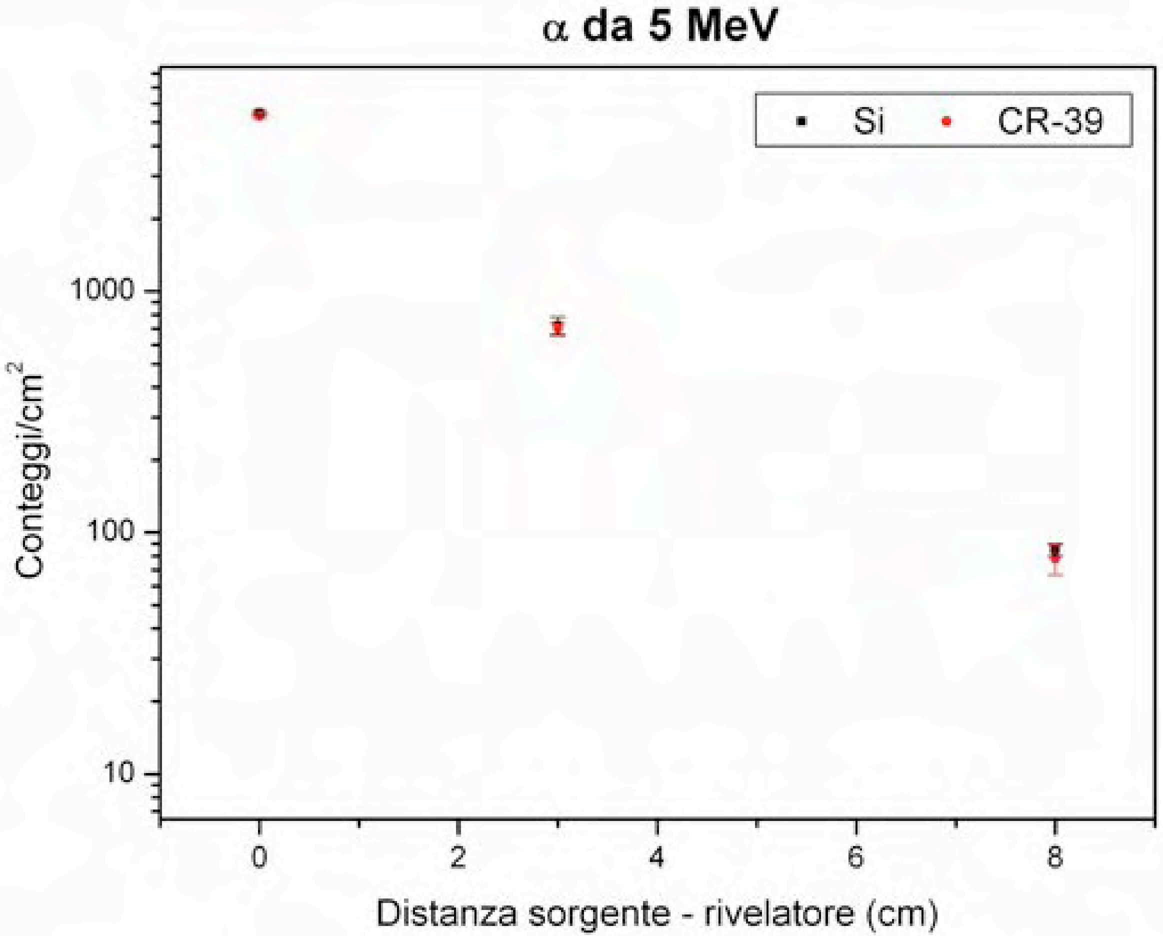


Numero di alfa da sorgente di Am ottenute dopo trattamento chimico.

Background tracks

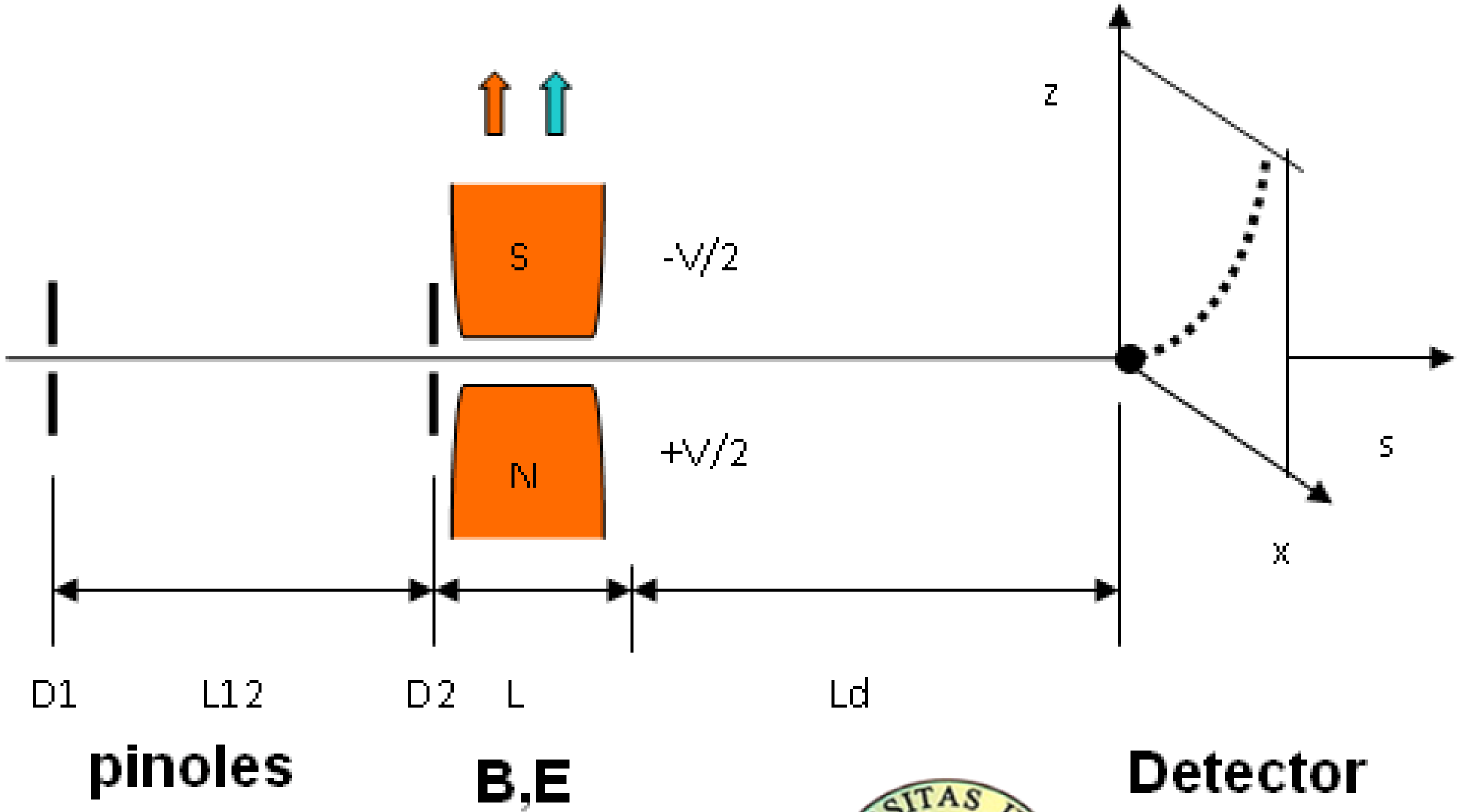


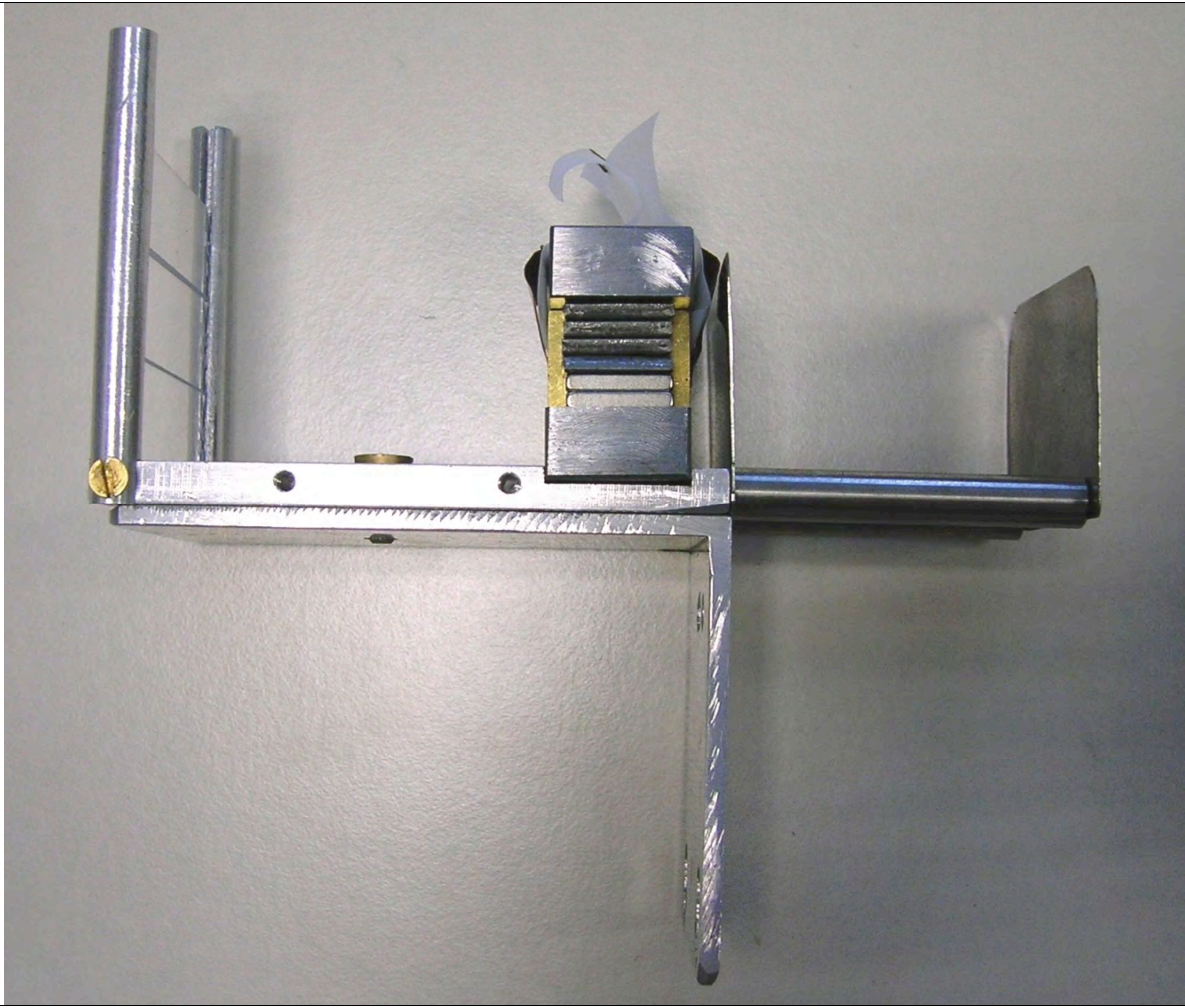
Confronto conteggi rivelatore al Si e Cr39



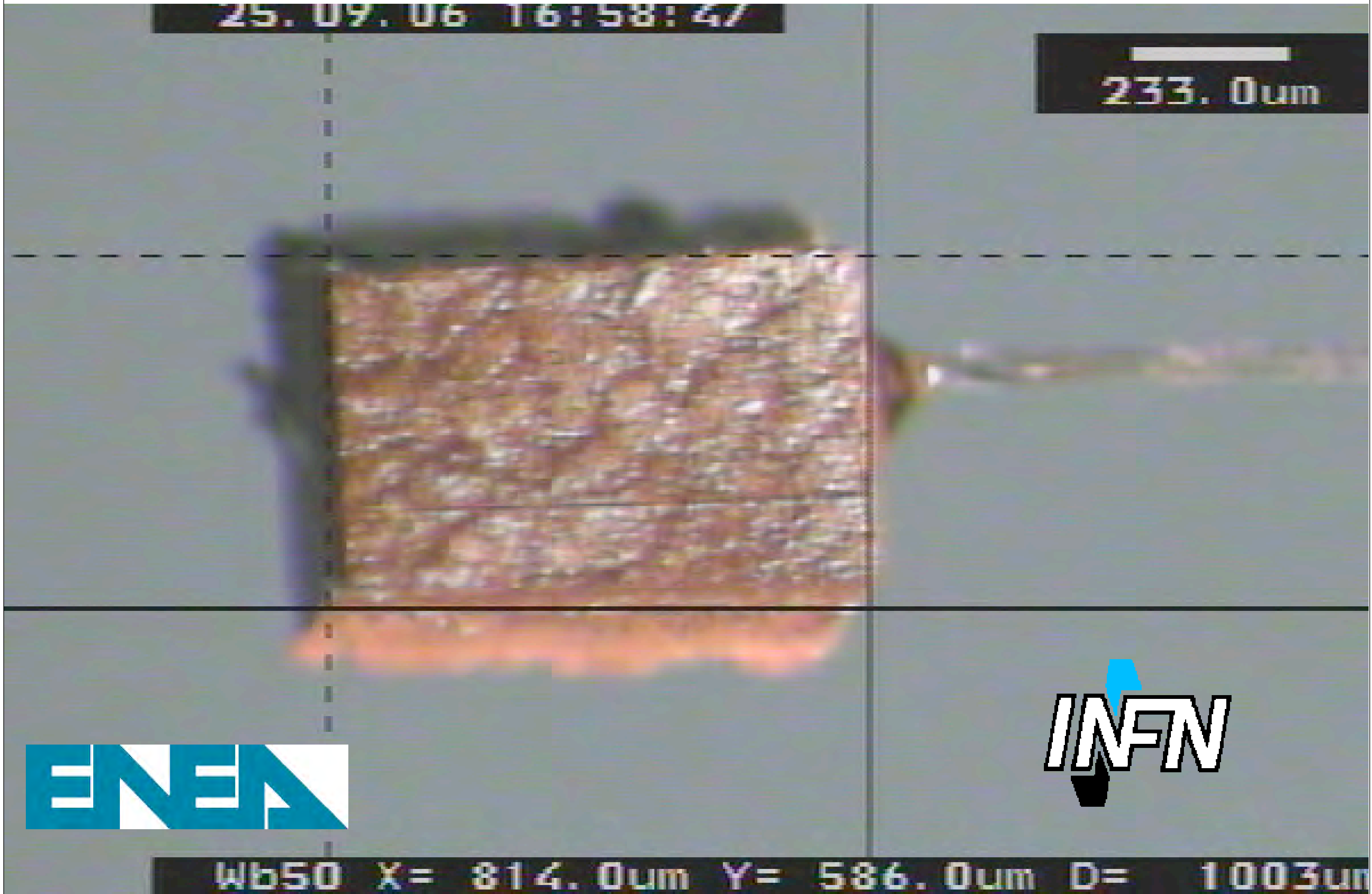
Progettazione parabola di Thomson

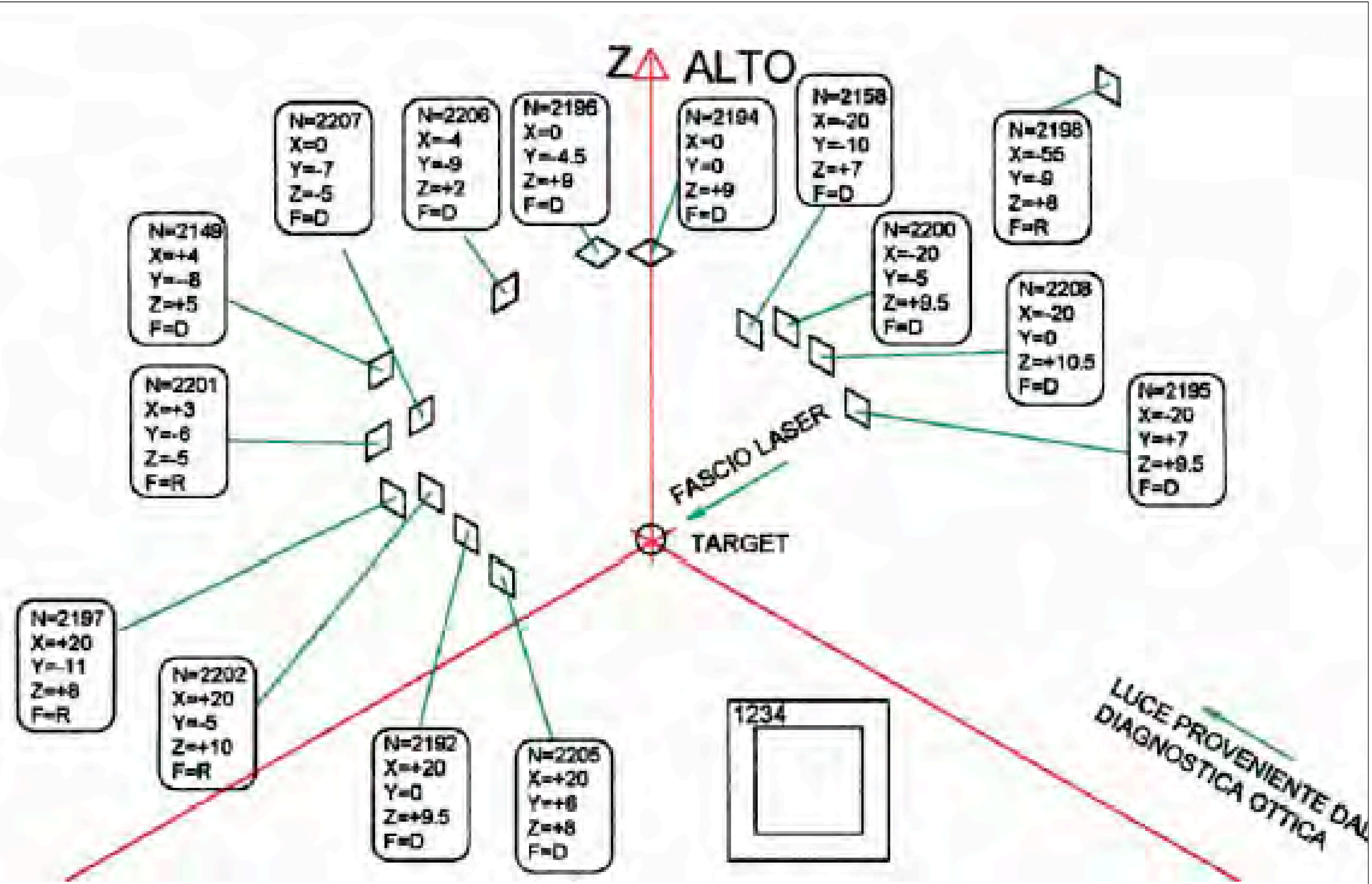
D.Leanza, master thesis, telecommunications eng., Kore University

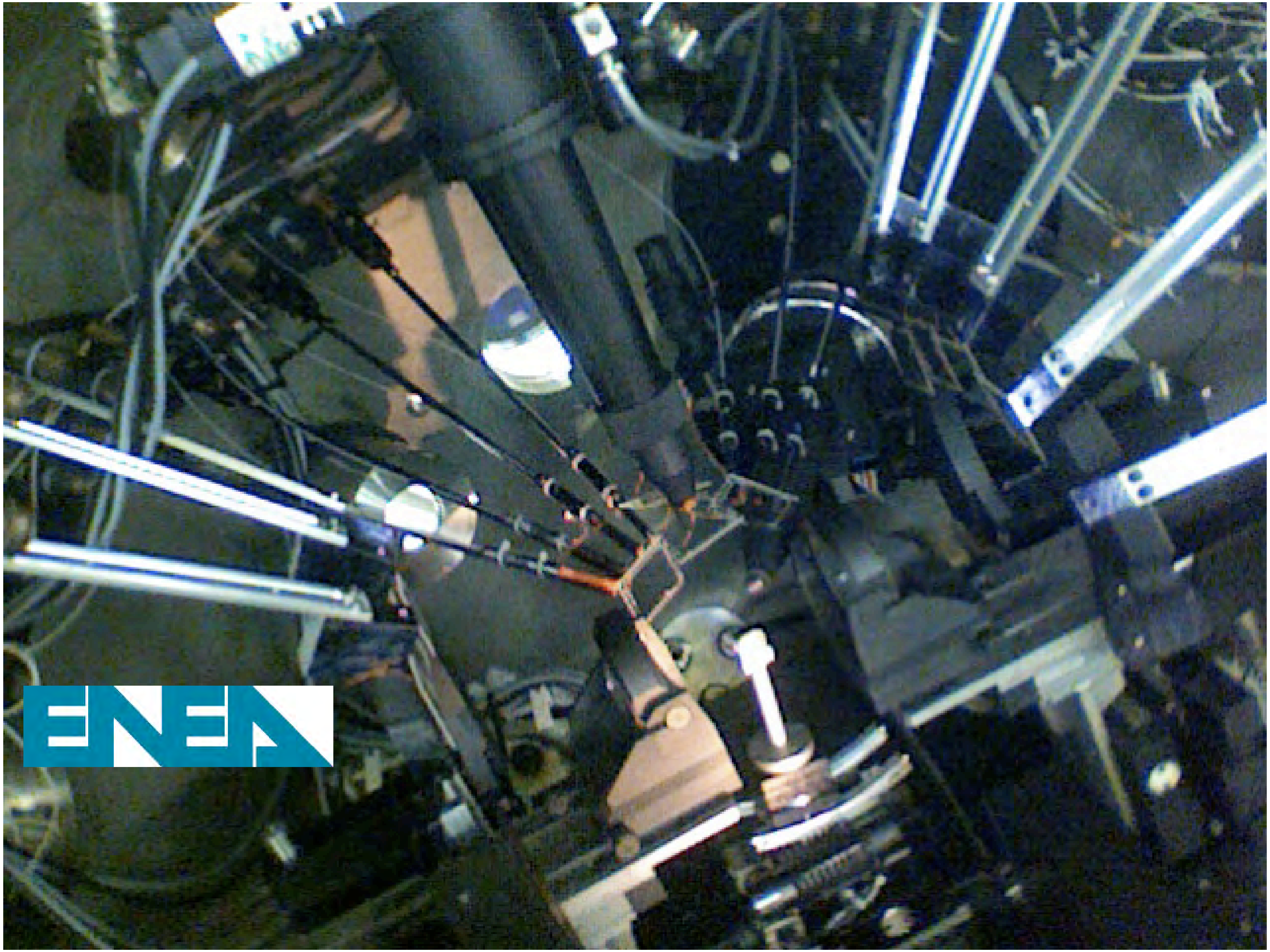


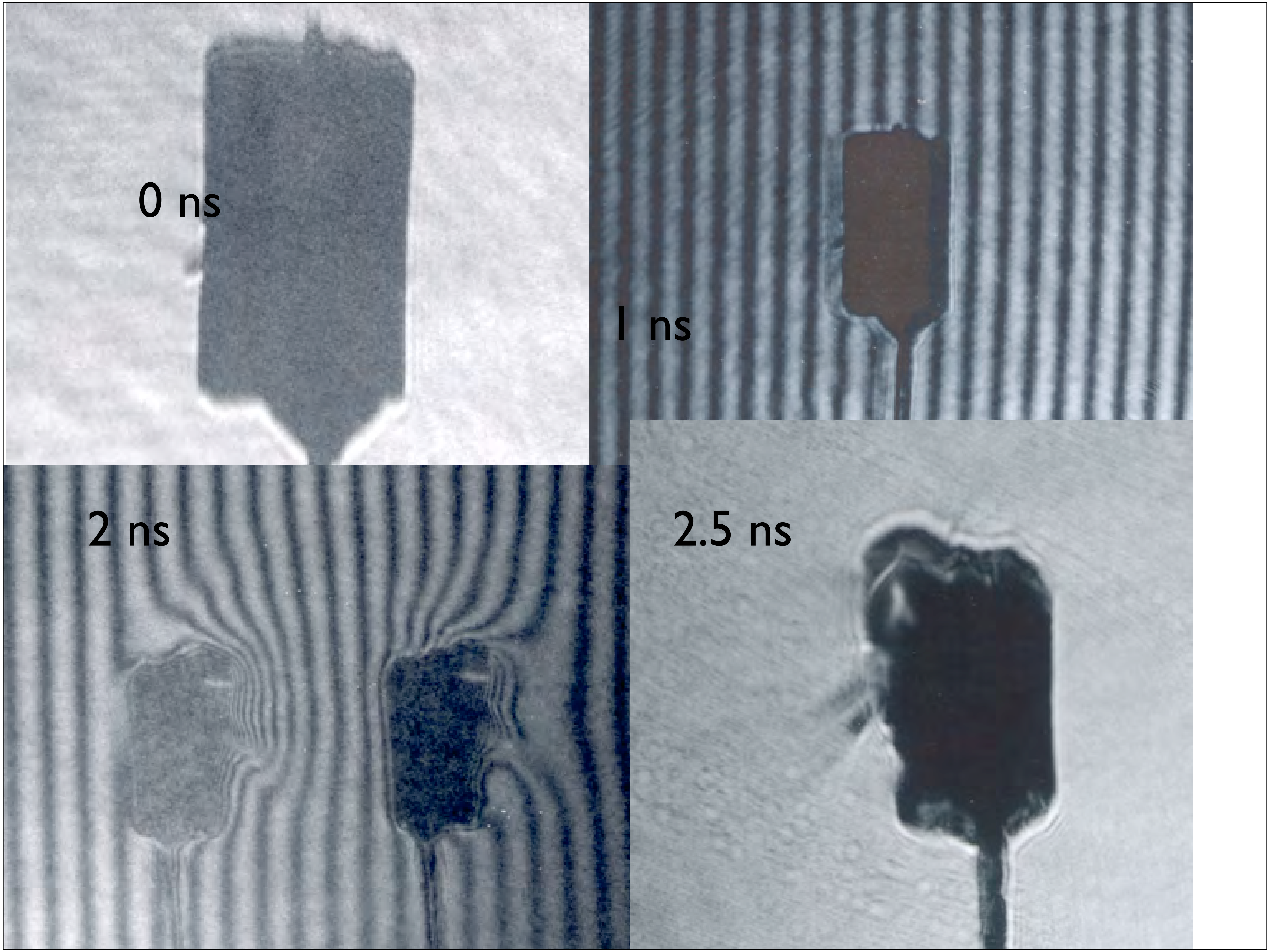


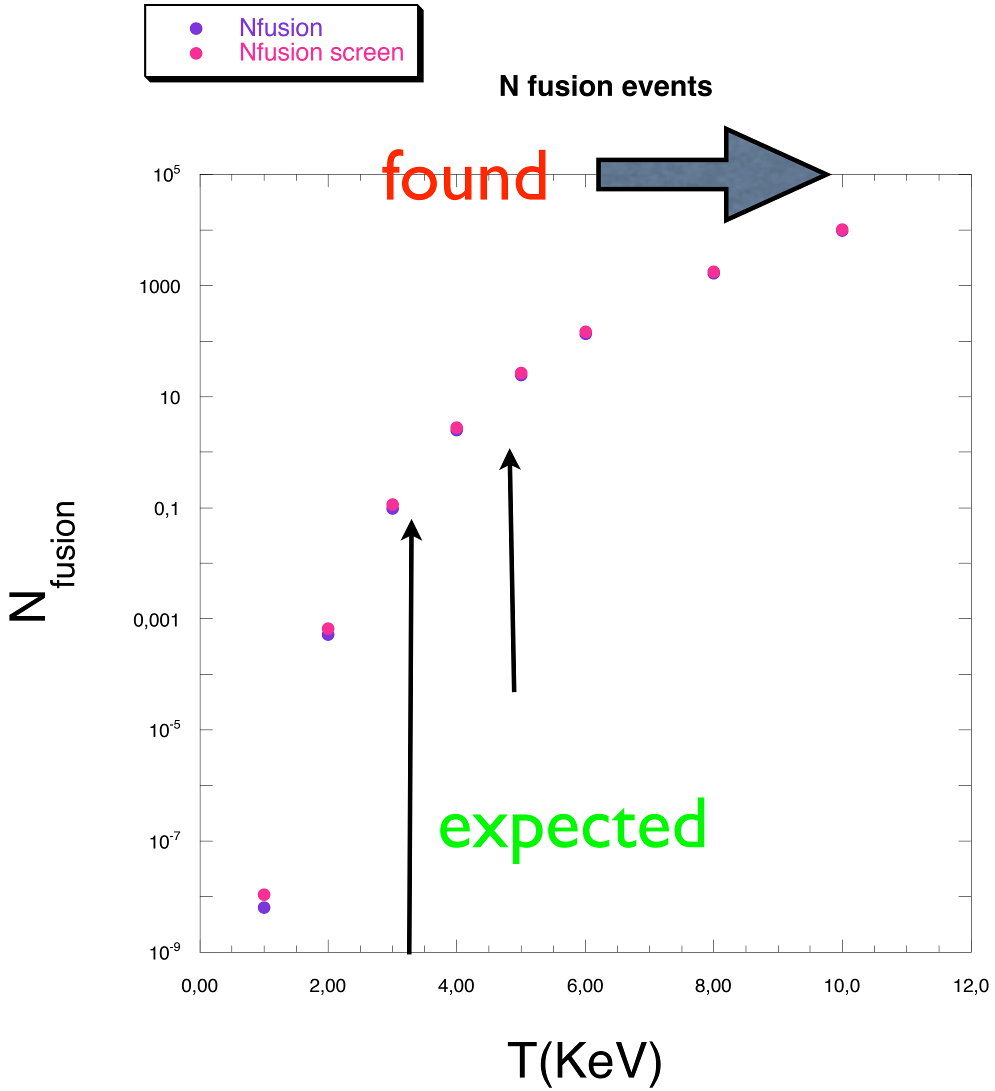

FILTER CIGARETTES
Marlboro
Il fumo
uccide
Marlboro
100's


25.09.06 16:58:47
233.0um
ENEA
INFN
Wb50 X= 814.0um Y= 586.0um D= 1003um


Z ALTO
N=2207 X=0 Y=-7 Z=-5 F=D
N=2206 X=-4 Y=-9 Z=+2 F=D
N=2196 X=0 Y=-4.5 Z=+9 F=D
N=2194 X=0 Y=0 Z=+9 F=D
N=2158 X=-20 Y=-10 Z=+7 F=D
N=2198 X=-55 Y=-9 Z=+8 F=R
N=2149 X=+4 Y=-8 Z=+5 F=D
N=2200 X=-20 Y=-5 Z=+9.5 F=D
N=2208 X=-20 Y=0 Z=+10.5 F=D
N=2201 X=+3 Y=-6 Z=-5 F=R
N=2195 X=-20 Y=+7 Z=+9.5 F=D
FASCIO LASER
TARGET
N=2197 X=+20 Y=-11 Z=+8 F=R
N=2202 X=+20 Y=-5 Z=+10 F=R
N=2192 X=+20 Y=0 Z=+9.5 F=D
N=2205 X=+20 Y=+8 Z=+8 F=D
1234
LUCE PROVENIENTE DAL
DIAGNOSTICA OTTICA

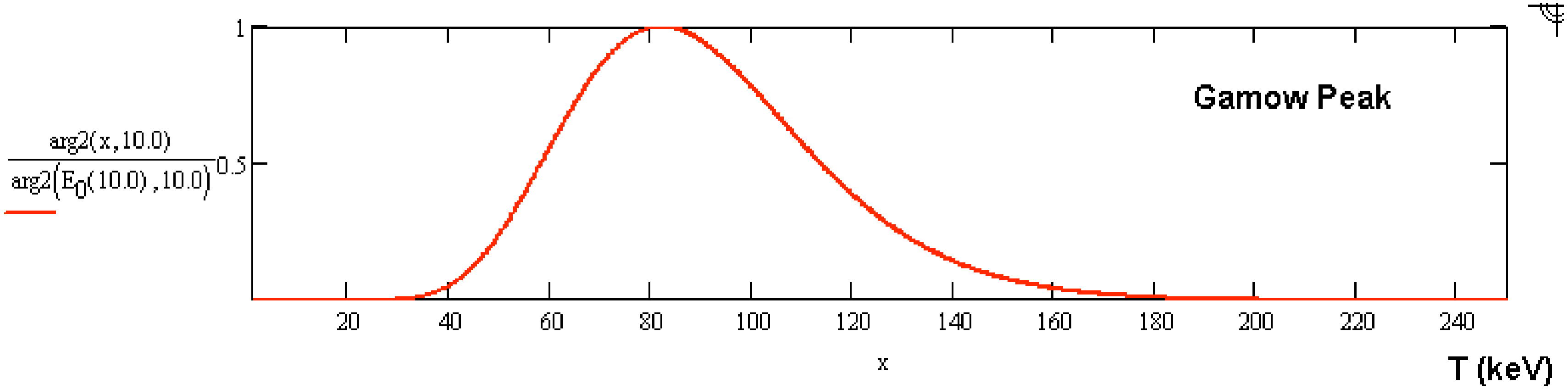

ENEA


0 ns
1 ns
2 ns
2.5 ns


Nfusion
Nfusion screen
N fusion events
found
expected
N_{fusion}
T(KeV)
10^5
1000
10
0,1
0,001
10^{-5}
10^{-7}
10^{-9}
0,00
2,00
4,00
6,00
8,00
10,0
12,0

Expected rates for an equilibrium system (for 1ns) AT NIF

T (kev)	E_gamow (keV)	Rate (cm^3/mol s)	alphas/cm^2 at 4 m
2.5	33	$2.6*10^{-4}$	0.04
5.0	52	$5.3*10^{-1}$	87
10	82	$2.1*10^{2}$	33,000



L. G. Sobotka and R.J. Charity

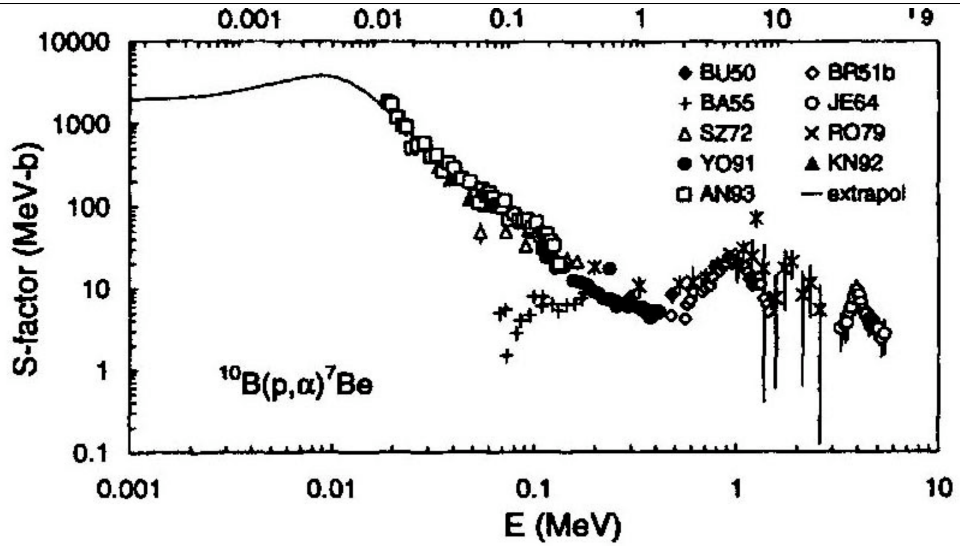
A few details

Can do shots with ^{10}B and ^{11}B separately. Carborane [$C_2B_{10}H_{12}$] can be readily obtained with either isotope with 99.9% purity. = 0.95 g/cm^3 , white powder.

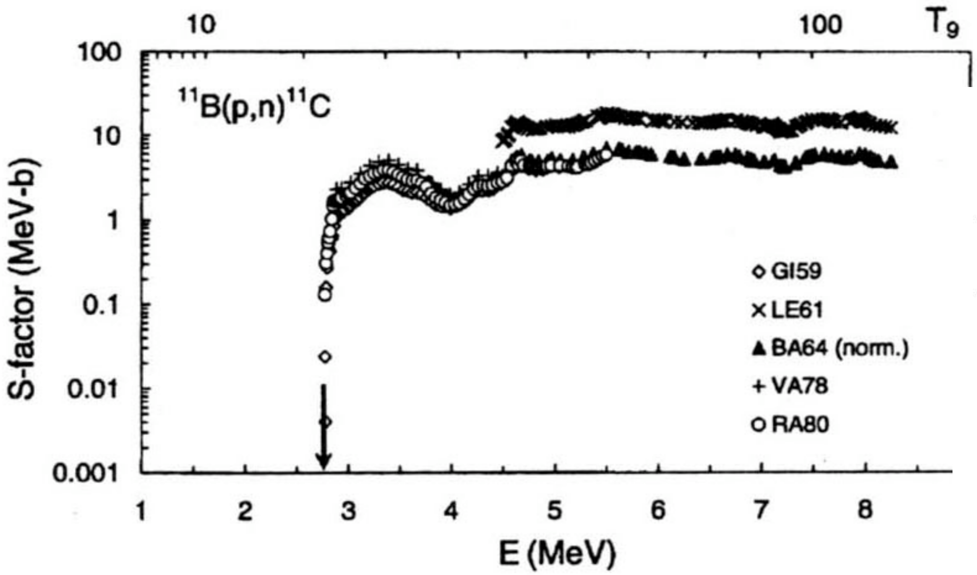
The energy analysis might prove interesting as the 16.11 state decays through $^8Be^*(2.9)$ while the 16.58 state decays through $^8Be^*(2.9)$ **and** $^8Be^{gd}$

CONCLUSIONS

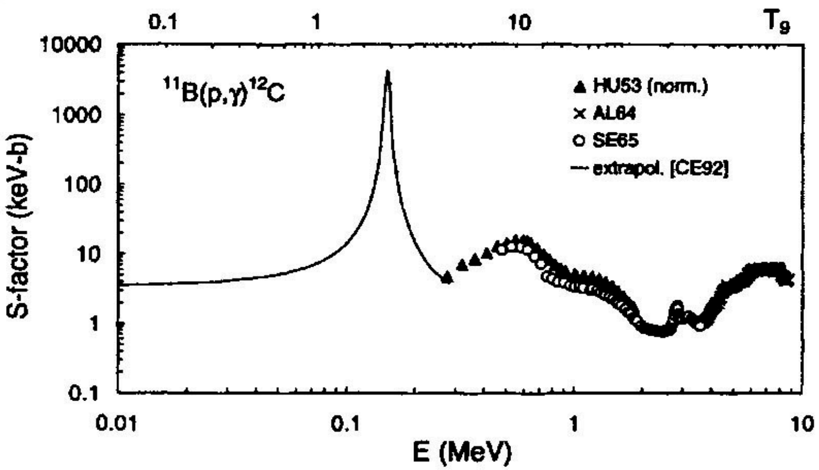
- Proposed experiments to measure S-factor in plasmas for p+B (but can be extended to other systems)
- Preliminary test at ABC laser faciliy very encouranging (low densities plasmas T=5-10 KeV): LAPLAFUS expt.
- Propose similar experiments but for compressed systems at NIF (Jupiter to begin). Expect similar T and hope for some 'surprises' as in LAPLAFUS.
- Are there screening effects in hot and dense plasmas?
- Can we use the electrons 'chaotic' motion to our advantage?



$^{10}B(p,\alpha)^7Be$
S-factor (MeV-b)
E (MeV)
T9
BU50
BR51b
BA55
JE64
SZ72
RO79
YO91
KN92
AN93
extrapol



$^{11}B(p,n)^{11}C$
S-factor (MeV-b)
E (MeV)
T9
GI59
LE61
BA64 (norm.)
VA78
RA80



$^{11}B(p,\gamma)^{12}C$
S-factor (keV-b)
E (MeV)
T9
HU53 (norm.)
AL64
SE65
extrapol. [CE92]